Poster Header:

The DC-8 Submillimeter-Wave Cloud Ice Radiometer

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Header Text box:

Submillimeter-wave cloud ice radiometry is an innovative technique for determining the amount of ice present in cirrus clouds, measuring median crystal size, and constraining crystal shape. The radiometer described in this poster is being developed to acquire data to validate radiometric retrievals of cloud ice at submillimeter wavelengths. The goal of this effort is to develop a technique to enable spaceborne characterization of cirrus, meeting key climate modeling and NASA measurement needs.

Section 1. Cirrus and Climate (Contains Fig1. Fig 2, fig3.)

Section 1. Banner Statement

Cirrus clouds affect Earth's climate and hydrological cycle by reflecting incoming solar energy, trapping outgoing IR radiation, sublimating into vapor, and influencing atmospheric circulation.

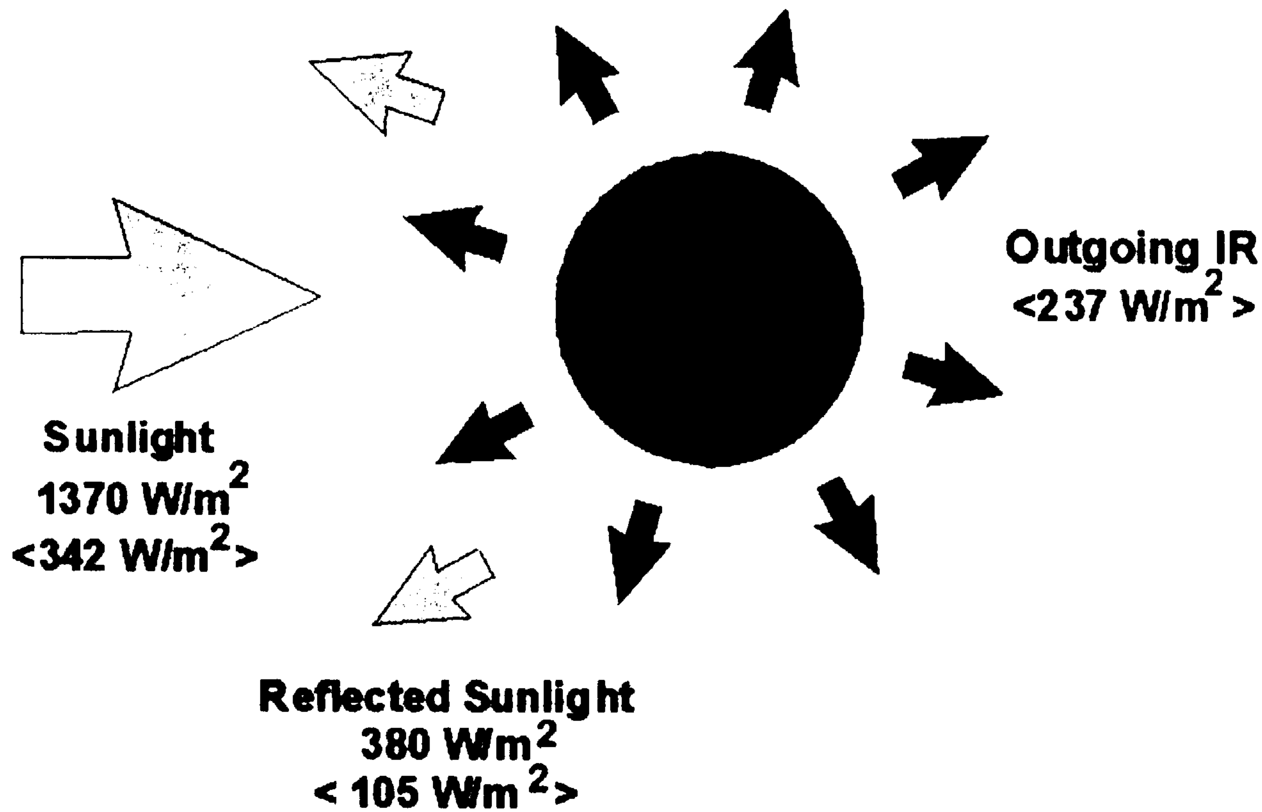
Section 1. Text Box:

Clouds are key to defining the Earth's energy balance. Clouds cool the Earth by reflecting incident sunlight back to space and warm the Earth by either absorbing upwelling thermal radiation and then re-radiating it back toward the surface or sublimating into water vapor, a potent greenhouse gas. Cloud-induced heating (or cooling) affects atmospheric circulation patterns. Changes in atmospheric circulation, in turn, affect cloud formation and alters cloud characteristics. This feed back relationship is central to understanding how clouds influence climate.

The accuracy of global circulation models (GCMs) used to predict climate variability and change depend on accurate quantitative models of the feedbacks linking clouds and circulation. At present, there are no direct comprehensive observations of mid- and upper- tropospheric ice to validate GCMs; hence there is a need for this technique to characterize cirrus.

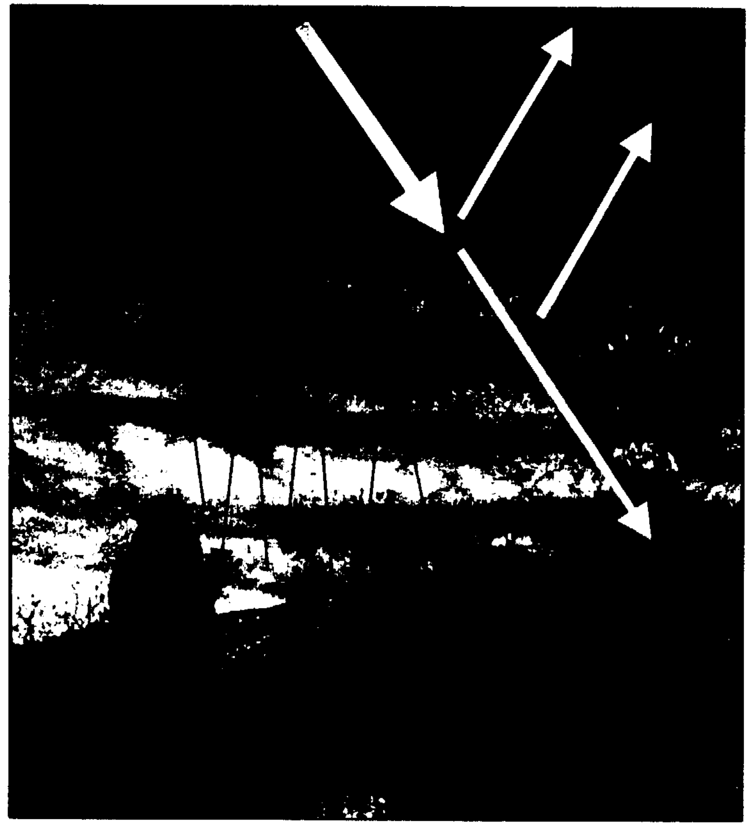
Cirrus are high-altitude clouds, that are made of ice. When they are thin, they have a wispy appearance due to falling streams of ice filaments.

Figure 1



The Earth's energy balance is strongly affected by clouds. Cirrus, in particular, are capable of strong radiative effects. Their cold temperatures and high altitudes limit the rate at which infrared energy can be radiated to space and allow them to reflect incident sunlight before a significant fraction can be absorbed by atmospheric gases.

Figure 2



Clouds cool the Earth by reflecting incident sunlight back to space and warm the Earth by either absorbing upwelling thermal radiation and then re-radiating it back toward the surface or sublimating into water vapor, a potent greenhouse gas. On average, cirrus clouds above six kilometers cover 30% of the earth, with tropical coverage exceeding 60%.

Figure 3

Section 2. Submillmeter-wave Cloud Ice Radiometry(Contains Fig4 – Fig9.)

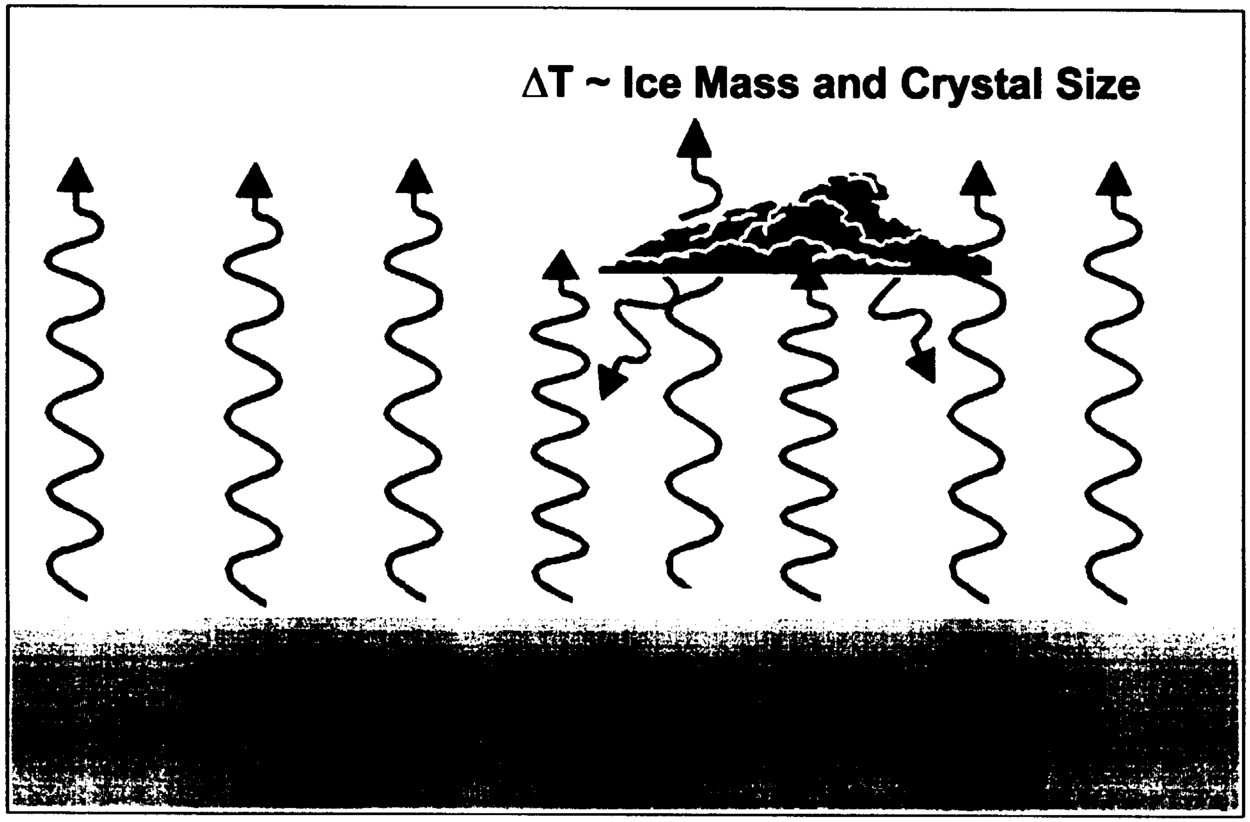
Section 2. Banner Statement
At submillimeter-wavelengths, cirrus scatters upwelling energy being radiated by lower tropospheric water vapor. Airborne and spaceborne radiometers measuring this change in flux are then able to retrieve both bulk and microphysical cloud properties.

Section 2. Text Box:

Using submillimeter-wave radiometry to retrieve properties of ice clouds can be understood intuitively.

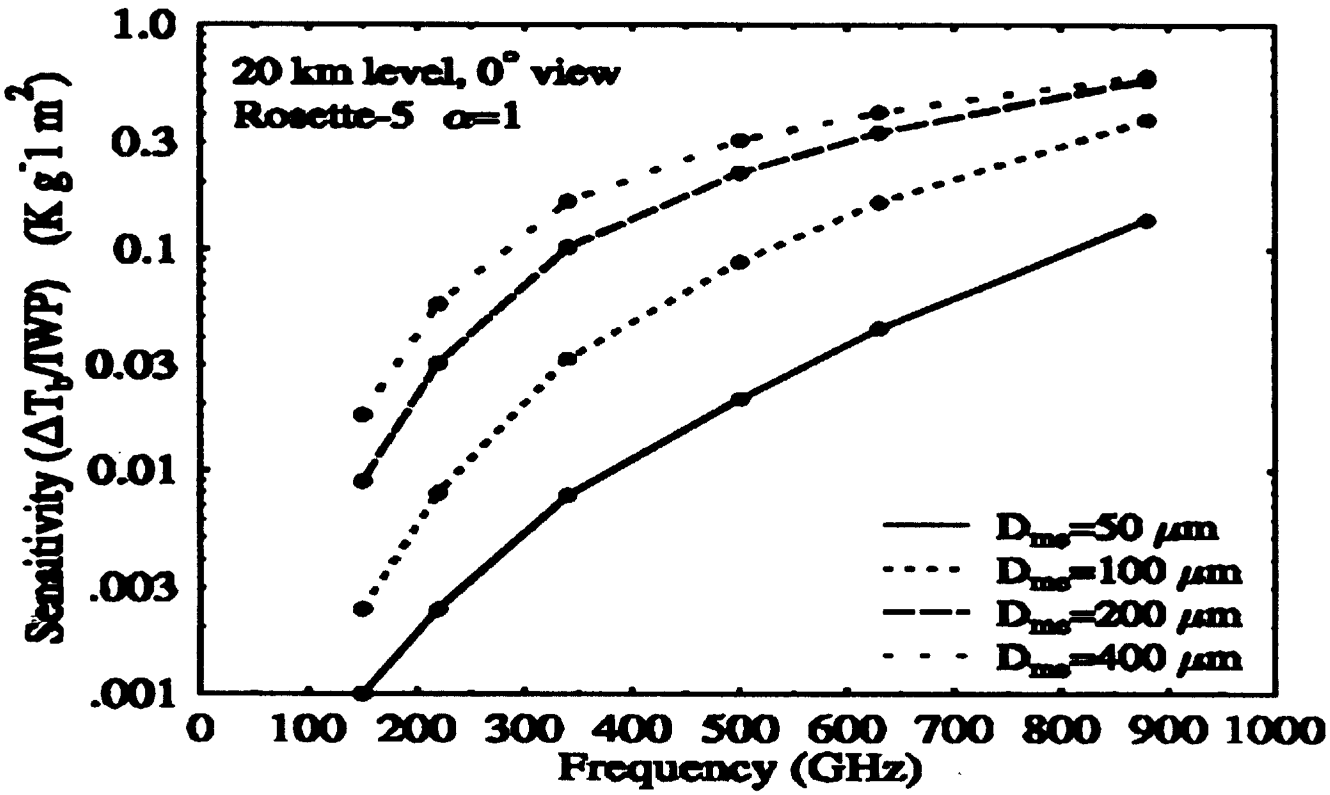
When cirrus clouds are present, they scatter the upwelling flux of submillimeter-wavelength radiation emitted by lower tropospheric water vapor reducing the upward flux of energy; hence, the power received by a down-looking radiometer decreases when a cirrus cloud passes through the field of view. Thus, cirrus clouds will appear radiatively cool against the warm lower atmospheric thermal emissions. Conversely, an uplooking radiometer will observe cirrus to be warm against the background of cold space.

The amount of energy scattered by a cirrus cloud is sensitive to both the amount of ice present and the size of the ice crystals. Therefore, variations in thermal flux caused by changes in median crystal size can be distinguished from changes in ice content with radiometric measurements made at several widely-spaced frequencies. Polarized measurements will aid in discriminating between different particle shapes.



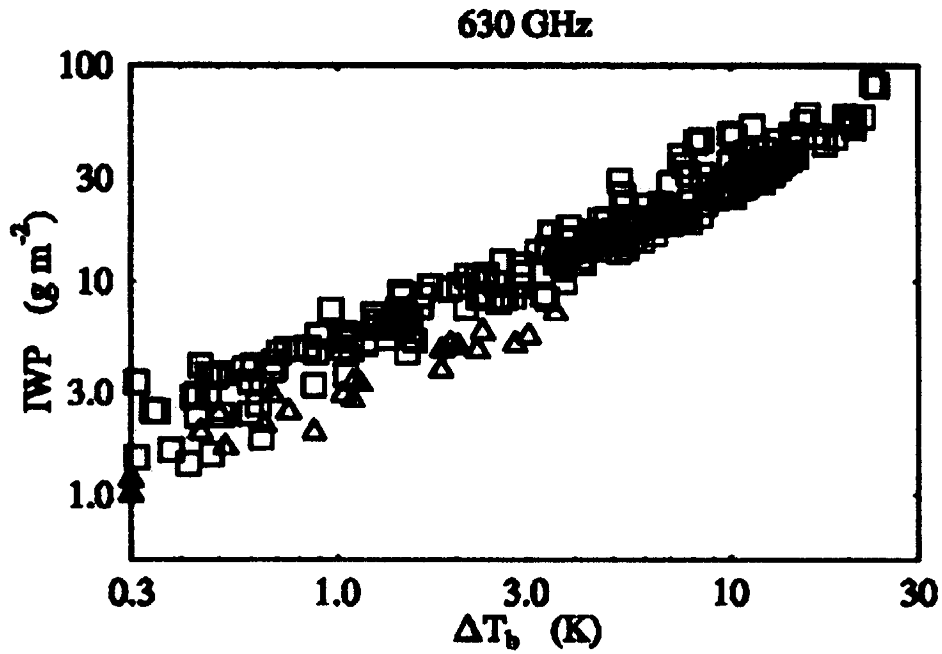
Cirrus scatters upwelling radiation from the lower troposphere which when viewed from above makes it appear radiatively cold against warm lower tropospheric emissions. The amount of radiation scattered is a function of both the total amount of ice and sizes of the crystals .

Figure 4



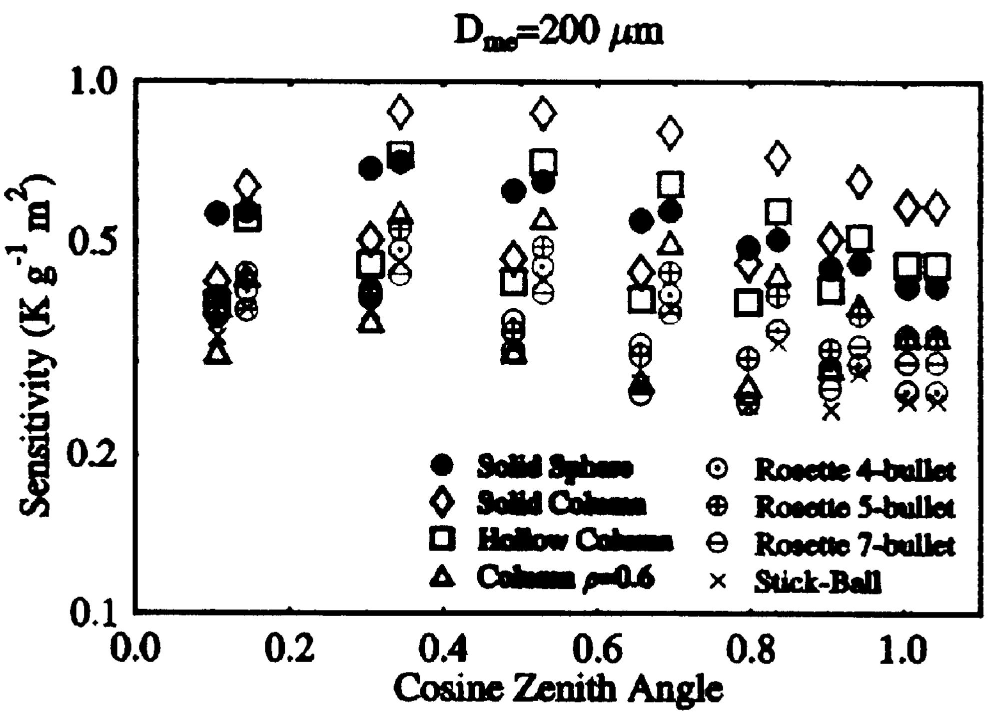
Radiometric sensitivity was calculated for rosette-shaped crystals using four sets of size distributions and unit ice water path. The signal (ΔT_B) increases with frequency and crystal size.

Figure 5



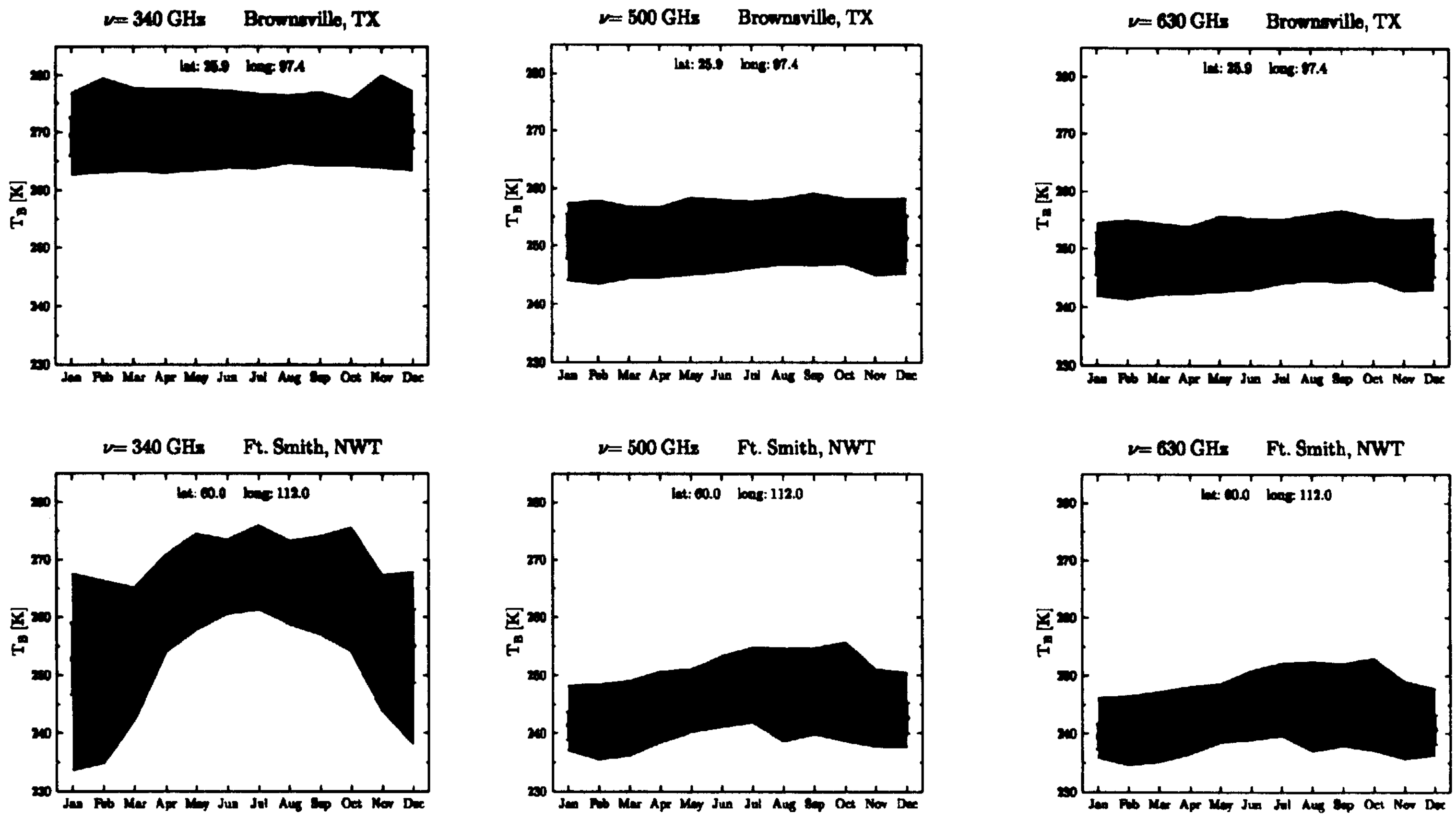
Calculation of magnitude of expected 630 GHz brightness temperatures based on in-situ measurements of crystal sizes and shapes.

Figure 6



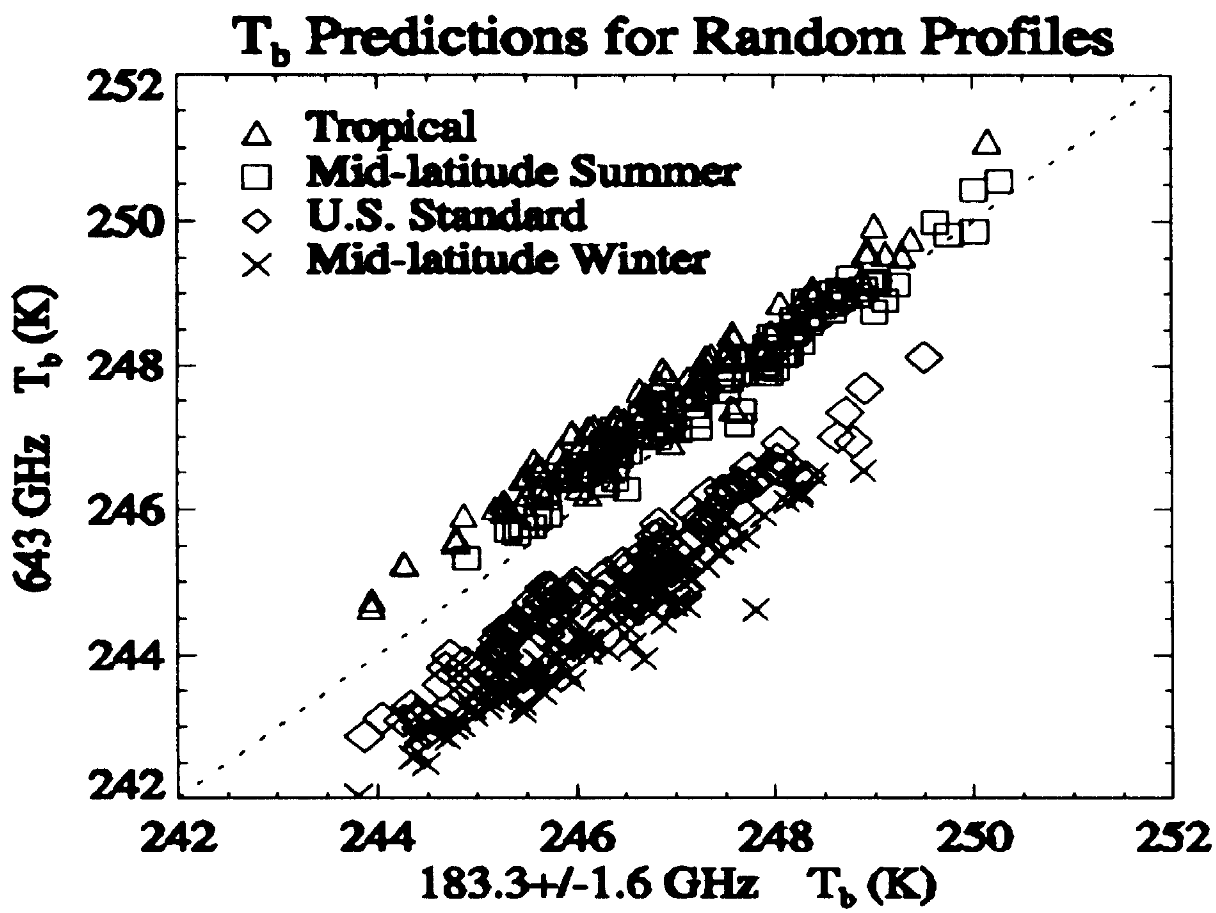
The effect of shape on crystal scattering is modeled for 200 μm crystals and 630 GHz. Ice crystals tend to fall with their long axis aligned horizontally. This creates a systematic difference between the vertical and horizontal extent of the crystals. Polarized measurements made off at an angle using should yield up to a 50% difference in brightness temperature between vertical and horizontal polarization, permitting the mean crystal aspect ratio ratio to be retrieved.

Figure 7



The atmospheric brightness temperature at a mid-latitude and polar site for three frequencies shows 5 K to 7 K degrees variability at the submillimeter wavelengths. In polar regions, the atmosphere becomes transparent at 340 GHz during the winter.

Figure 8



Correcting for variability in the water vapor background relies on clear sky brightness temperatures at 183 GHz being well correlated with those at 643 GHz. Due to the presence of a water vapor spectral line at 183 GHz, these two frequency bands have the same opacity but much different sensitivity to water vapor.

Figure 9

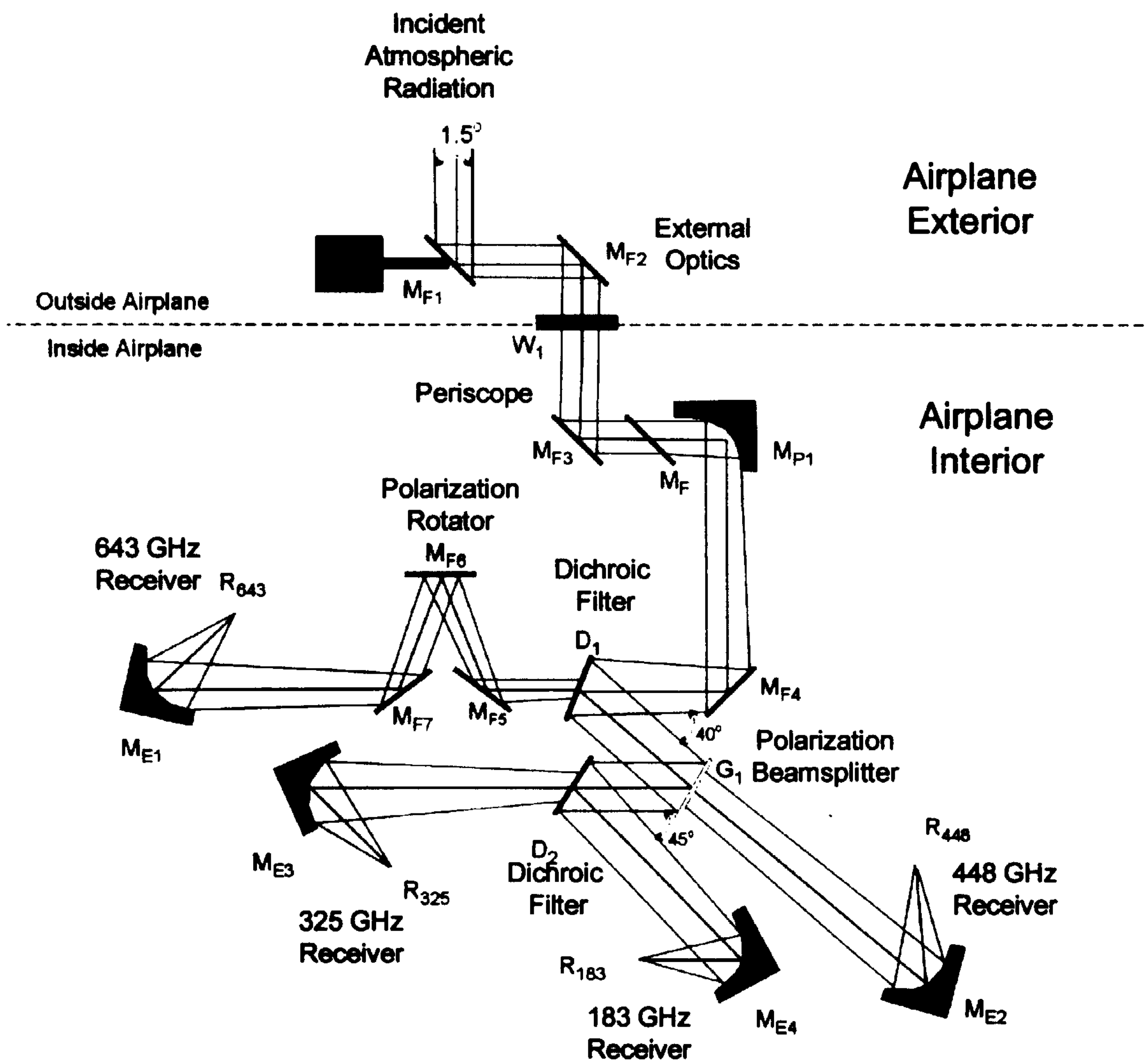
Section 3. DC-8 Submillmeter-wave Cloud Ice Radiometer (Contains Fig 10 – Fig17.)

Section 3. Banner Statement

The DC-8 submillimeter-wave airborne cloud ice radiometer is a four-frequency, dual polarization radiometer that will be able to scan cross-track from zenith to near-nadir from an aircraft passenger aircraft.

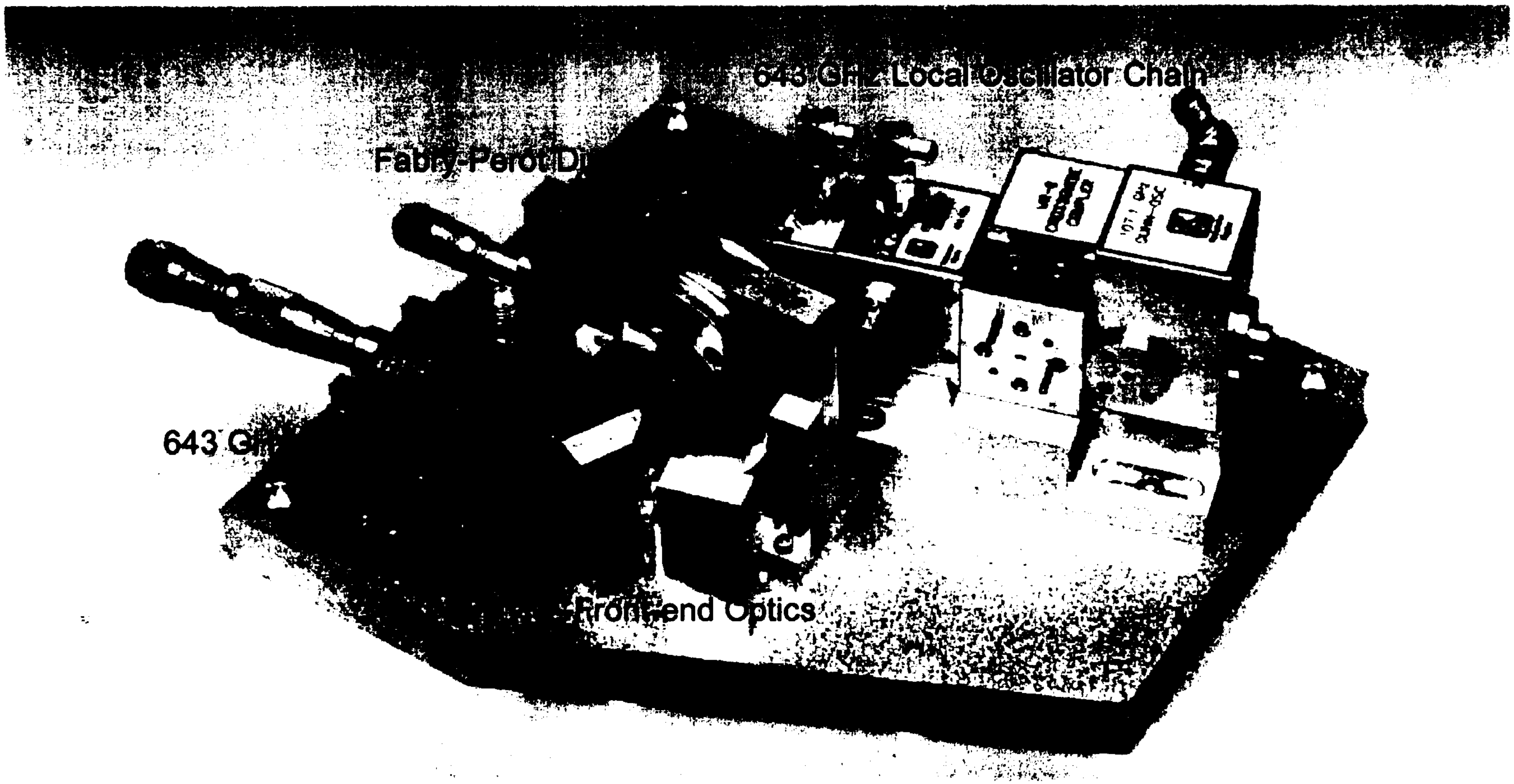
Section 3. Text Box:

The DC-8 submillimeter-wave cloud ice radiometer is being designed to make measurements at four frequencies (183 GHz, 325 GHz, 448 GHz, and 643 GHz) with dual-polarization capability at 643 GHz. The instrument is being developed for flight on NASA's DC-8 and will scan cross-track through a modified passenger window. Measurements with this radiometer in combination with independent ground-based and airborne measurements will validate the submillimeter-wave radiometer retrieval techniques.



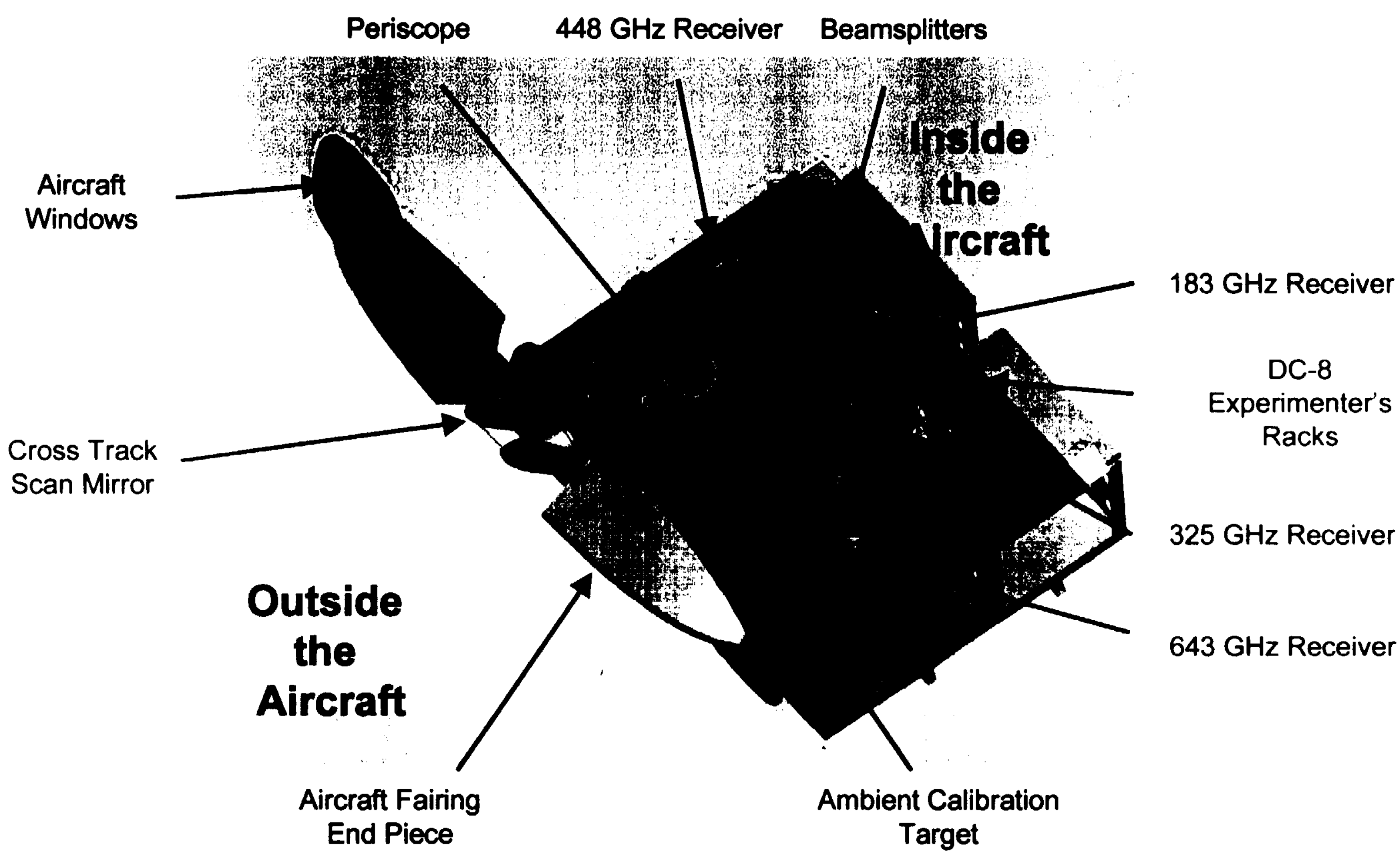
The DC-8 cloud ice radiometer quasi-optical design.

Figure 10



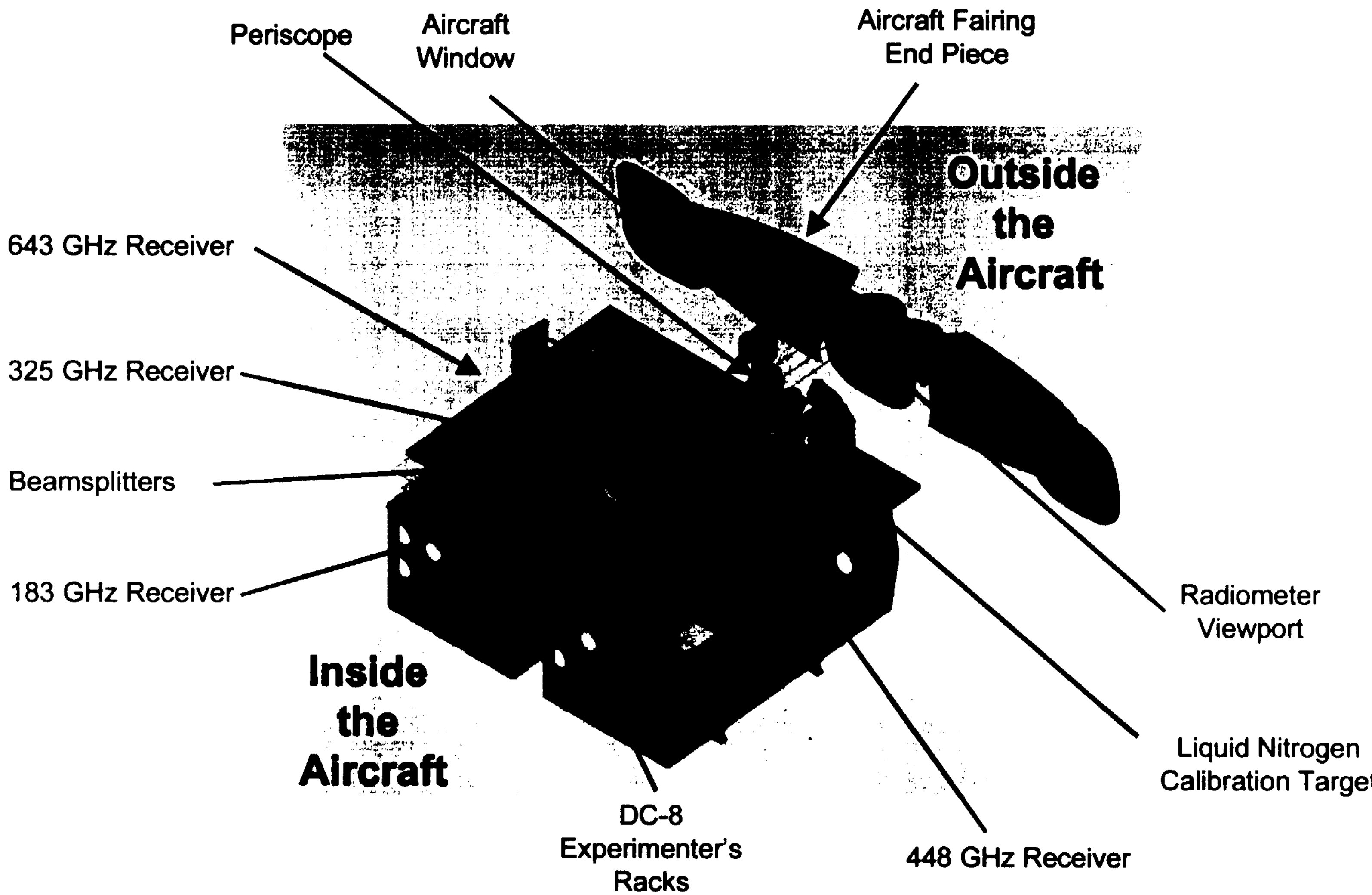
The 643 GHz receiver front-end is based on planar-Schottky technology.

Figure 11



The Cloud Ice Radiometer Mechanical Design: Outside View

Figure 12



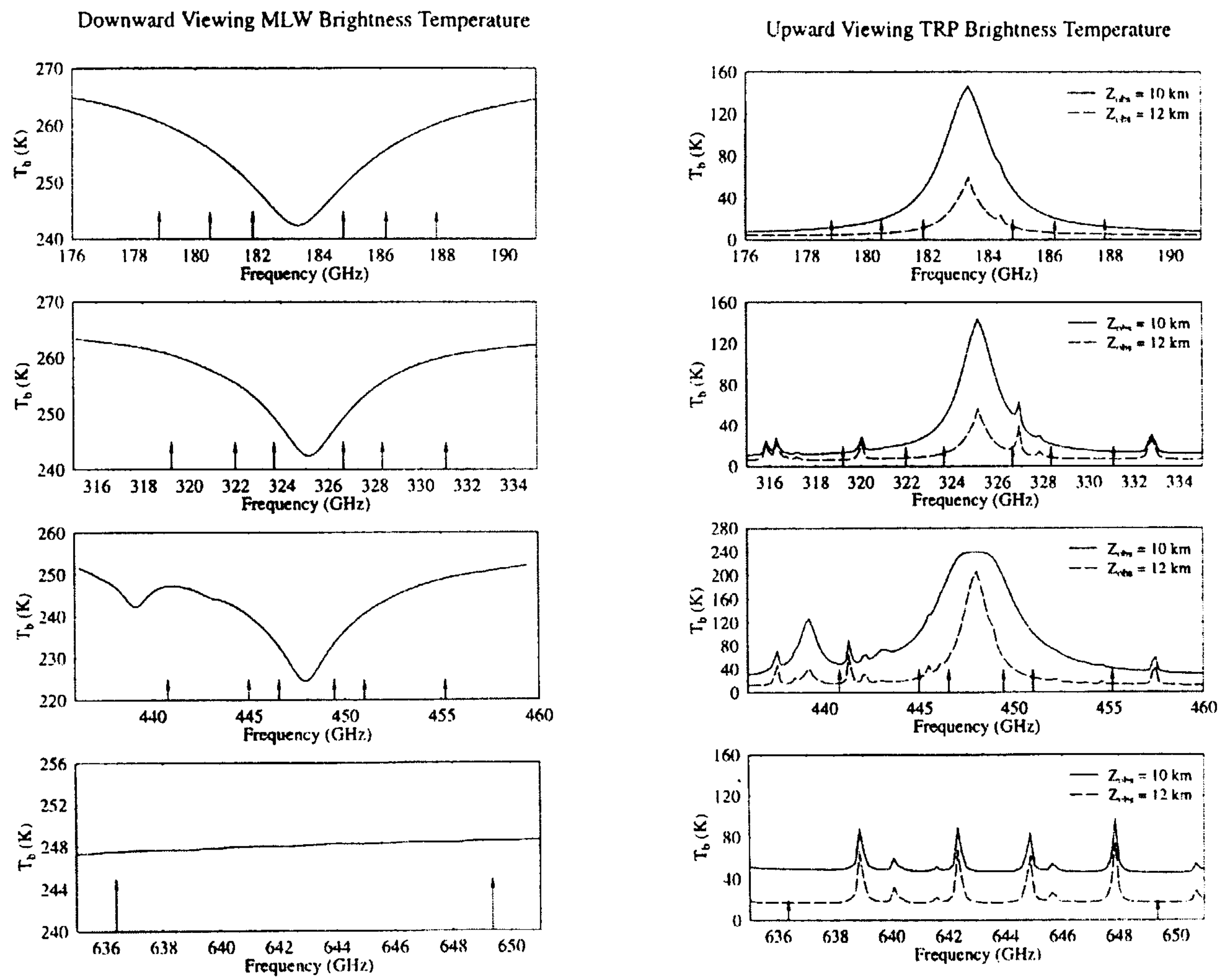
The Cloud Ice Radiometer Mechanical Design: Inside View

Figure 13

Top-level DC-8 Cloud Ice Radiometer Specifications

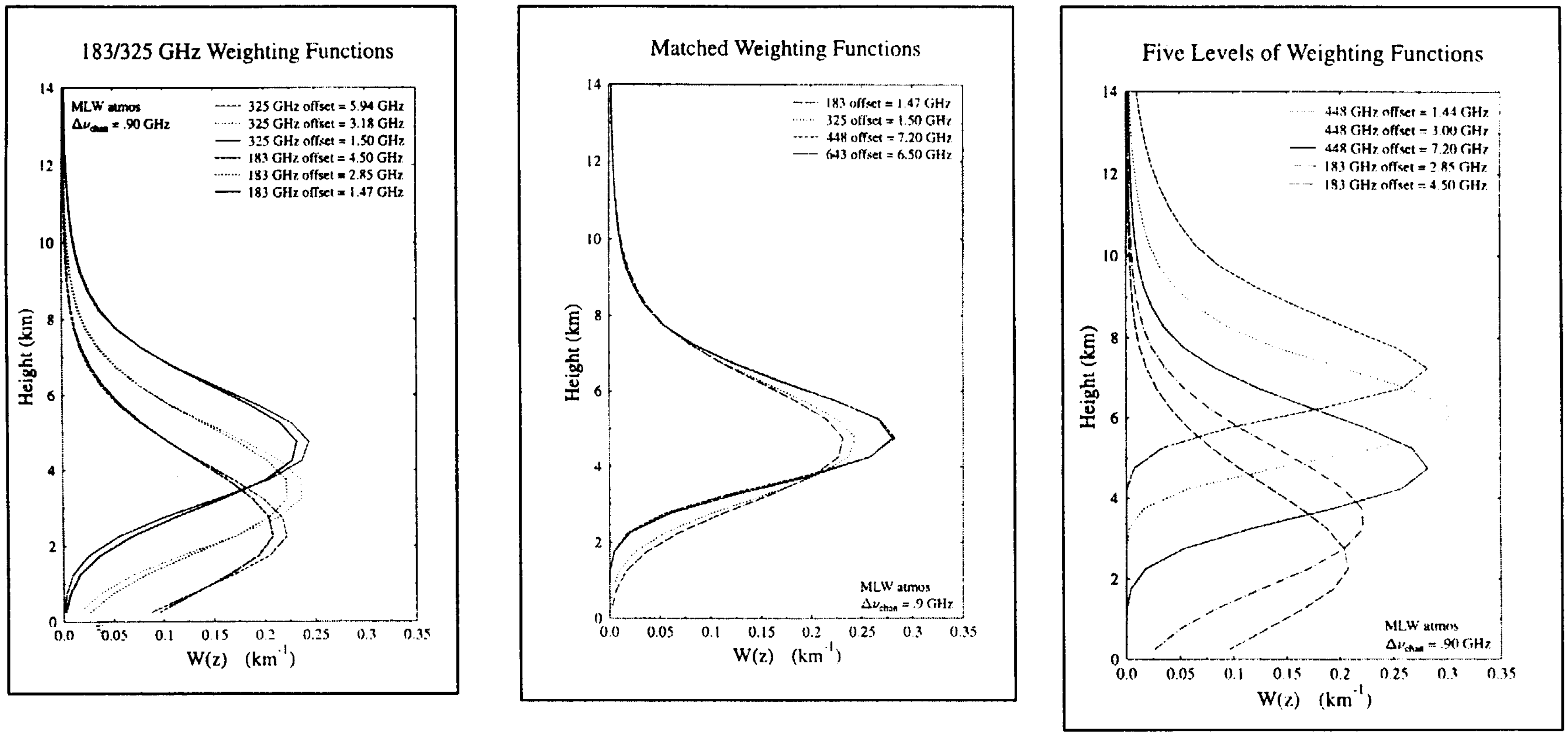
Center Frequencies	643 GHz
	450 GHz
	325 GHz
	183 GHz
Brightness Temp. Precision	< 0.5 K
Brightness Temp. Accuracy	< 1.0 K
Radiometer System Noise	< 5000 K
3 dB Beamwdith	1.5 degree
Elevation Scanning Range	-70 o to +90 o
Polarization	Orthogonal linear
Internal Calibration	Ambient target and cold load
External Calibration	Tip curves

Figure 14



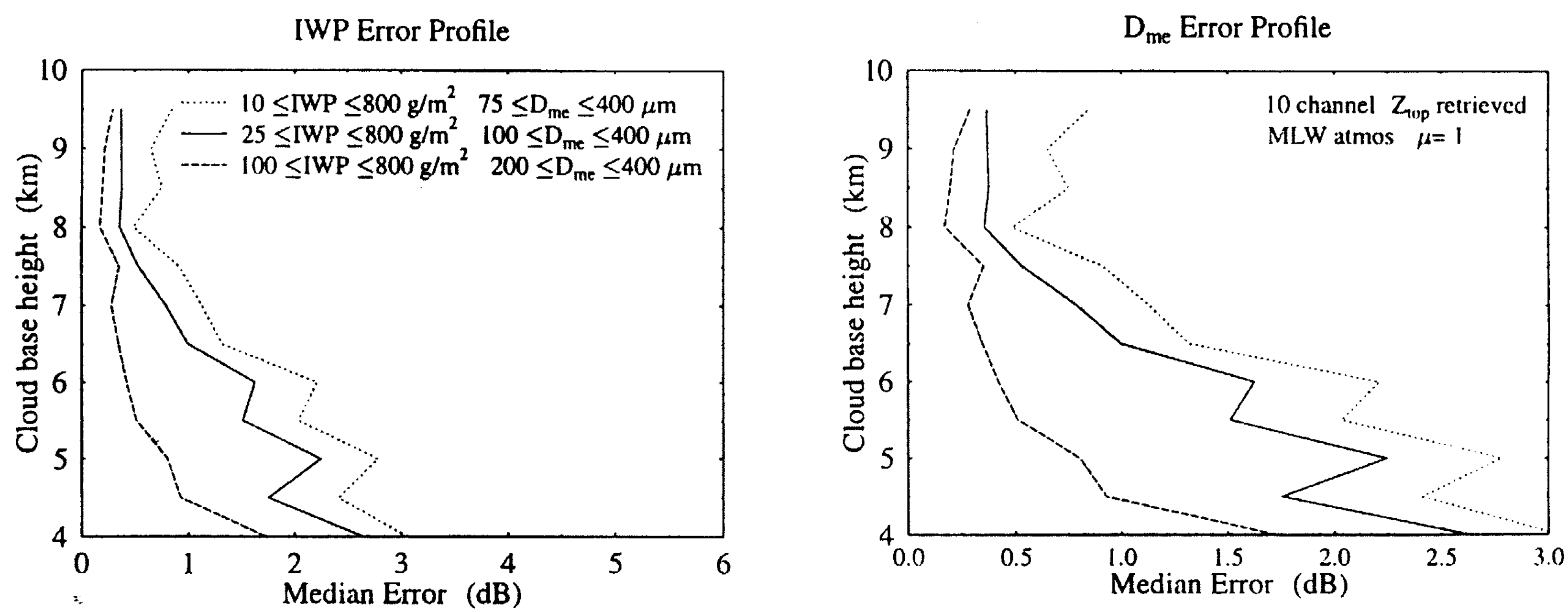
The frequency bands selected for the cloud ice radiometer plotted against mid-latitude atmospheric spectra.

Figure 15



The atmospheric weighting functions for the chosen radiometer frequencies

Figure 16



The profile of the error expected in integrated water path (cirrus ice content) and the ice crystal size retrievals expected from the DC-8 cloud ice radiometer.

Figure 1

Poster Footnote:

ACKNOWLEDGMENTS

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